Draft Final

Hunters Point Naval Shipyard Estimated Excess Cancer Risks from Potential Radiological Exposures in Buildings Report

Prepared under:
Contract No. N44255-14-D-9013
Task Order No. N6247318F5420

Prepared by:
BATTELLE
505 King Ave.
Columbus, OH 43201

July 22, 2021

CONTENTS

TABLES

1 Introduction

This report describes the calculation of estimated excess cancer risks resulting from potential, future exposures to radiological dust contamination in impacted buildings (structures) at the former Hunters Point Naval Shipyard (HPNS) in San Francisco, California. HPNS was placed on the National Priorities List in 1989 and the Department of the Navy (DON) has been undertaking response actions under its Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) authority in each parcel. These actions are conducted to ensure radionuclide-specific radioactivity concentrations on building surfaces do not exceed the remediation goals (RGs) stated in the 2006 Action Memorandum (AM) (NAVFAC, 2006). The RGs presented in Table 1 were intended to be the most conservative available, to be applied using the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM, USEPA 2000), and to be applied to material-specific background levels. For each radionuclide of concern (ROC), the RGs are the lower of the surface concentration limits in Regulatory Guide 1.86 (AEC 1974) or the surface concentration which resulted in 25 millirem (mrem) per year using RESRAD-BUILD, Version 3.3. Building surface RGs are presented in units of disintegrations per 100 square centimeters and in the equivalent units of picoCuries per square meter.

Table [SEQ Table * ARABIC \s 1]. Current Building Surface Remediation Goals from 2006 HPNS Action Memorandum

Radionuclide of Concern	Building Surface Remediation Goals (dpm/100 cm^2)	Building Surface Remediation Goals (pCi/m^2)
Americium (Am)-241 (^{241}Am)	100	4,500
Cesium (Cs)-137 (^{137}Cs)	5,000	225,000
Cobalt (Co)-60 (^{60}Co)	5,000	225,000
Europium (Eu)-152 (^{152}Eu)	5,000	225,000
Eu-154 (^{154}Eu)	5,000	225,000
Plutonium (Pu)-239 (^{239}Pu)	100	4,500
Radium (Ra)-226 (^{226}Ra)	100	4,500
Strontium (Sr)-90 (^{90}Sr)	1,000	45,000
Thorium (Th)-232 (^{232}Th)	36.5	1,640
Tritium, H-3 (^{3}H)	5,000	225,000
Uranium (U)-235 (^{235}U)	488	22,000

In support of the current five-year review, the Navy is evaluating the protectiveness of the current building surface RGs for future occupants, both indoor workers and residents. Under CERCLA, cleanup goals are considered protective if excess cancer risks to the reasonably, maximum exposed individual remain within the excess lifetime cancer risk range of 10^{-4} to 10^{-6}. The conceptual site model (CSM) outlines the exposure conditions and assumptions that define inputs into the risk estimation model. This CSM is described in Section 2 and represents a very conservative scenario in which future building occupants may be exposed to radioactively contaminated dust for long periods.

The Navy uses the model RESRAD-BUILD to estimate radiation risks from exposure to surface radiological contamination. RESRAD-BUILD, Version 3.5 ([HYPERLINK "http://resrad.evs.anl.gov/codes/resrd-build/"]) is a downloadable computer code, developed jointly by the Department of Energy and the Nuclear Regulatory Commission. It is considered the industry standard for estimating risk to human health and the environment resulting from exposure to radioactively contaminated building surfaces.

Section 2 provides an overview of the conceptual site model used to define the exposure conditions being modeled. Section 3 describes the site-specific inputs used in RESRAD-BUILD and provides the resultant risks to potential, future residents.

2 Conceptual Site Model

This section describes the exposure conditions and assumptions, based on the HPNS CSM, used to determine the site-specific input parameters in RESRAD-BUILD. All radioactive sources were removed from buildings before the permanent cessation of shipyard operations in 1989. Subsequent building surveys identified a few localized areas of residual contamination that have been remediated and resurveyed. Any radioactivity available for ingestion is assumed to be in the form of contaminated dust that has settled onto building floors and lower walls (six foot or two meters high). Consistent with the conditions under which the RGs were developed, and with the long period of building inactivity, 20% of any surface contamination is assumed to be loose or ingestible.

Future occupants may include indoor workers or residents, both having the potential for inadvertent ingestion of contaminated dust or external exposure to it. Since future residents would spend significantly more time in a building than would workers, they have a higher potential for both ingestion and external exposure risks, and they are modeled as the reasonably maximum exposed individual. An individual is assumed to reside in the modeled area for 26 years, with exposure durations of 15.2 hours daily and 350 days yearly. Residents are assumed to inadvertently ingest all loose, contaminated dust through hand-to-surface and subsequent hand-to-mouth contacts within this exposure duration (totaling 138,320 hours). Dust that is fixed to the surface contributes to resident external exposures.

Residents are assumed to live in renovated portions of these large, industrial buildings with daily exposures occurring in a 10-foot by 10-foot room. The floor (10 ft x 10 ft) and two adjacent lower walls (each 10 ft x 6 ft) are assumed to uniformly covered with contaminated dust. The other two walls and ceiling are assumed to be new construction and therefore free of contaminated dust.

Each surface is assumed to be loaded with dust at concentrations equal to each ROC RG (Table 1). Since many of the ROCs decay to radioactive progeny within a 100-year period, the progenies were also modeled at concentrations equal to that of their parent, known as secular equilibrium. A series of sequential radioactive progenies form a decay chain. For the ROCs listed in Table 1:

- The parent radionuclides ^{60}Co, ^{154}Eu and ^{3}H have no radioactive progeny.
- The parent radionuclides ^{137}Cs, ^{226}Ra, ^{90}Sr and ^{232}Th reach equilibrium and are modeled with equal progeny concentrations.
- The parent radionuclides ^{241}Am, ^{152}Eu, ^{239}Pu and ^{235}U do not reach equilibrium and are modeled without progeny concentrations.

3 Calculation of Risk Using RESRAD-BUILD

This section summarizes the user-provided inputs and changes to default parameter values (presented in Table 2) needed to calculate the site-specific risks from building surface exposures.

3.1 Slope Factor Library

Slope factors, or risk coefficients, are the increased lifetime risks of cancer incidence attributable to the intake of, or external exposure to, a unit amount of radioactive material. Ingestion and inhalation slope factors are expressed as risk/pCi and external exposure slope factors as risk/yr per pCi/cm^2. A custom library was created using the RESRAD Dose Conversion Factor (DCF) Editor, Version 2.5 (2009) embedded as a tool in RESRAD-BUILD. The custom library, called HPNS DCFPAK 3.02, updates the slope factors for each radionuclide of interest to the latest values published by the Oak Ridge National Laboratory's Center for Radiation Protection Knowledge from Version 3.02 of their DCFPAK code.

The slope factors in the custom library are those most applicable to future exposures in HPNS buildings. The "soil population" slope factors apply to soil and dust ingestion and are averaged over all ages in a population. The "ground plane" slope factors apply to external exposure to surface soil or dust contamination of any density.

3.2 Time Parameters

The total time of exposure to contaminated dust depends on the product of the exposure duration, the indoor fraction, and the time fraction in RESRAD-BUILD. The exposure duration is the number of days of residency in the building. For residents, the exposure duration is 350 days per year for 26 years based on the recommendations in Attachment 1 of USEPA, 2014. The indoor fraction is the unitless portion of each day spent in the residence during the exposure duration. The value of 0.64 represents a resident spending 15.3 hours daily in the residence, calculated from the age-weighted mean time indoors at a residence in Table 16-1 of USEPA, 2011. The time fraction is the unitless portion of time indoors that the residence is exposed to contaminated dust. Based on the CSM, the resident spends all their indoor time in the 10-ft x 10-ft room and the time fraction is therefore unity (1.0).

3.3 Receptor Parameters

As discussed in Section 3.2, the resident is assumed to be in the same room as contaminated dust when they are in the building and the time fraction is 1.0. Since the room is small, their position is in the center of the room which results in external exposure from the floor and the two contaminated walls, but also accounts for ingestion of the loose dust.

3.4 Source Parameters

Three sources were modeled, representing the two adjacent lower walls and the floor as presented in Table 3 and Figure 1. Each source is located at its center coordinates for proximity to the receptor. The input concentrations are presented with the other site-specific input values in Table 2. Each source contains each ROC at the RG, as well as the long-lived progenies of Ra-226 and Th-232 (italicized). The short-lived progenies of Cs-137 (Ba-137m), Pu-239 (U-235m), Sr-90 (Y-90), and U-235 (Th-231) are included by RESRAD-BUILD at concentrations equal to their parents and the associated risks are included with those of the parent in the output. This is also true for all the short-lived progenies in the Ra-226 and Th-232 decay chains.

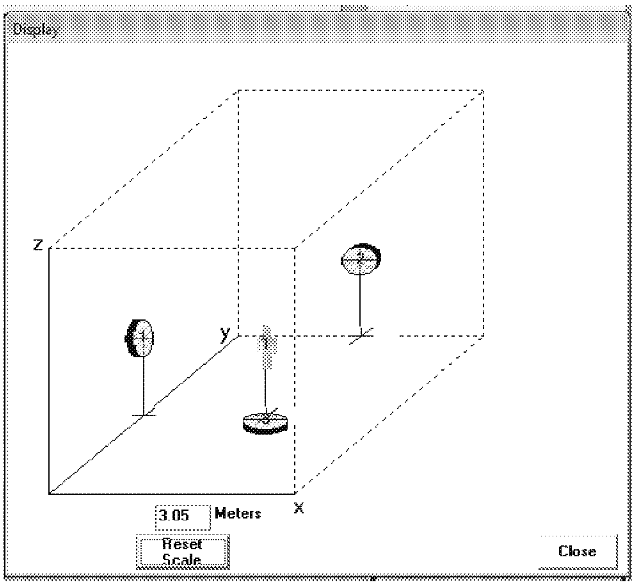
Table 2. Site-Specific Input Values Used in RESRAD-BUILD

Input Tab	Parameter	Default Value	Site-Specific Value
Case	Risk Library	FGR 13	DCFPAK 3.02
Time Parameters	Exposure Duration (d)	365	9,100
	Indoor Fraction	0.5	0.64
Receptor Parameters	Time Fraction	1	1
	Location (X, Y, Z) (m)	1, 1, 1	1.52, 1.52, 1
Source Parameters	Location and Dimensions	n/a	See Table 3
	Air Fraction	0.1	0
	Direct Ingestion Rate (1/h)	0	7.19E-06
	Removable Fraction	0.5	0.2
	Lifetime (d)	365	3.65E+06
	Source Concentrations		See Table 5

Table 3. Source Locations and Dimensions Used in RESRAD-BUILD

Source #	Description	Type/Direction	Location of Center (X, Y, Z) (m)	Dimensions (X, Y, Z) (m)
1	Wall 1	Area/X	0, 1.52, 1	0, 3.05, 2
2	Wall 2	Area/Y	1.52, 3.05, 1	3.05, 0, 2
3	Floor	Area/Z	1.52, 1.52, 0	3.05, 3.05, 0

Figure 1. Source and Receptor Locations Used in RESRAD-BUILD



The building conditions are assumed be static, meaning contaminated dust is not deposited, resuspended, or dissipated due to passive or forced ventilation, erosion, cleaning, foot traffic, etc. The removable fraction is the unitless portion of the total source activity that is loose and available for ingestion. The removable fraction was decreased from the default of 0.5 to 0.2 for all radionuclides to be consistent with the CSM and the assumptions used to develop the RGs.

The air fraction is the unitless portion of loose dust that becomes airborne and is respirable. Consistent with the CSM, the air fraction is decreased from the default value of 0.1 to zero, meaning none of the removable fraction is inhaled but remains available for direct ingestion. The air fraction must also be set to zero to maintain mass balance in the model because the direct ingestion rate is so large as to match the removal rate of loose dust. When the air fraction is zero, the deposition, immersion, inhalation, and indirect ingestion pathways are suppressed, and the building parameter and indirect ingestion rate inputs are effectively ignored.

The direct ingestion rate is the portion of the loose dust ingested each hour. It was calculated as the inverse of the total hours the resident was exposed to loose dust over the 26 years, or 1/139,055 hours, resulting in a rate of 7.19E-06 h^{-1}. This very conservatively forces the ingestion of all the removable fraction of each source within the exposure period.

Lifetime is the period over which the removable fraction is eroded due to routine activities and cleaning. Because the building is being modeled without source dissipation, the lifetime was increased from the default 365 days to 3.65E+06 days to effectively eliminate any source losses from erosion.

The radon release fraction is the portion of the radon gas (Rn-222) produced as a progeny of Ra-226, or thoron gas (Rn-220) produced as a progeny of Th-232, that escapes the source without resulting in any risk contribution. The default of 0.1 was reduced to zero to ensure the radon and thoron progenies plated out onto the contaminated dust and the risks associated with their subsequent progeny were accounted for.

3.5 Risk Results

The results presented in Table 4 are the peak ingestion and external exposure risks, occurring at time = 0, retrieved from the *Risk by Pathway Detail* and *Risk by Nuclide Detail* sections of the output Risk Report. Cancer risk is reported as the lifetime cancer risk accumulated throughout the exposure period. If they are within the 10^{-4} to 10^{-6} range, the cleanup goals are considered protective for the associated receptors.

Table 4. Source Input Concentrations and Calculated Resident Risks from RESRAD-BUILD

Parent ROC	Contributing Progeny	Input Concentration (pCi/m^2)	Ingestion Risk	External Exposure Risk	Total Risk
^{241}Am		4,500	3.51E-06	5.25E-08	3.6E-06
^{60}Co		225,000	1.09E-05	5.32E-05	6.4E-05
^{137}Cs	*^{137m}Ba*	225,000	3.15E-05	3.20E-05	6.3E-05
^{152}Eu		225,000	7.97E-06	4.90E-05	5.7E-05
^{154}Eu		225,000	1.08E-05	4.06E-05	5.1E-05
^{3}H		225,000	4.72E-08	0.00E+00	4.7E-08
^{239}Pu	*^{235m}U*	4,500	4.44E-06	2.25E-09	4.4E-06
^{226}Ra	*^{222}Rn+D*	4,500	1.31E-05	2.51E-06	
	^{210}Pb+D	*4,500*	3.40E-05	9.66E-09	5.1E-05
	^{210}Po+D	*4,500*	1.65E-06	4.06E-08	
^{90}Sr	*^{90}Y*	45,000	1.99E-05	3.70E-06	2.4E-05
^{232}Th		1,640	1.31E-06	7.19E-10	
	^{228}Ra+D	*1,640*	1.41E-05	4.68E-07	2.2E-05
	^{228}Th+D	*1,640*	5.21E-06	7.34E-07	
^{235}U	*^{231}Th*	22,000	1.47E-05	1.33E-06	1.6E-05

As shown in Table 4, the current HPNS building RGs result in risks that fall within the stated risk management range and are therefore considered protective for future resident occupancies. The reported risks are the maximum, bounding risk estimates for the modeled exposure scenarios.

4 Summary

This report describes the use of RESRAD-BUILD to estimate the excess cancer risks to potential, future residents from contaminated dust exposures in HPNS buildings. The assumptions and methods used in this report are very conservative and the use site-specific data and realistic exposure scenarios would result in lower risk estimates. However, the current estimated risks remain within the 10^{-4} to 10^{-6} range, indicating that remedial goals in the 2006 Action Memorandum are protective for future building occupants.

5 References

Atomic Energy Commission (AEC 1974), Regulatory Guide 1.86. *Termination of Operating Licenses for Nuclear Reactors*. June.

Naval Facilities Engineering Command (NAVFAC 2006), Southwest. *Final – Basewide Radiological Removal Action: Action Memorandum – Revision 2006, Hunters Point Shipyard, San Francisco, CA*. April.

United States Environmental Protection Agency (USEPA 2014), *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors*, OSWER Directive 9200.1-120. Office of Superfund Remediation and Technology Innovation. Washington, DC. February. Accessed at [HYPERLINK "https://epa-bprg.ornl.gov/documents/OSWER_Directive_9200.1-120_ExposureFactors_corrected2.pdf"].

United States Environmental Protection Agency (USEPA 2011), *Exposure Factors Handbook, Activity Factors*, November. Accessed [HYPERLINK "https://www.epa.gov/sites/default/files/2015-09/documents/efh-chapter16.pdf."]

United States Environmental Protection Agency (USEPA 2000), Department of Energy, Nuclear Regulatory Commission, and Department of Defense. 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*. NUREG-1575, Rev. 1. EPA 402-R-97-016, Rev. 1. DOE/EH-0624, Rev. 1. August.

Appendix A. RESRAD-BUILD Dose Output Files

Appendix B. RESRAD-BUILD Risk Output Files